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ABSTRACT

This study investigated the effects of different structures of a synthesizer and formats of the generality component on the application and remember levels of learning. Seventy-three undergraduates participated. Four treatment groups were formed by combining two types of structure (complete versus partial) with two types of format in generality (visual versus verbal statement). A complete synthesizer contained a generality, an example, and some practice. A box-chart diagram was used to represent the visual format of the generality. Results suggest that, although the format of the generality does not make significant differences on either the application or the remember levels of learning, a complete synthesizer seems to benefit remember level learning. When comparing treatment groups with the control group, the post-hoc comparison again shows that complete synthesizers result in significantly better learning than no synthesizer at all. A discussion of the findings concludes the paper. Seventeen references are appended. (Author/RP)

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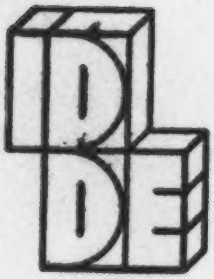

INSTRUCTIONAL DESIGN, DEVELOPMENT, AND EVALUATION

WORKING PAPERS

THE EFFECTS OF FORMAT AND STRUCTURE OF A SYNTHESIZER ON PROCEDURAL-DECISION LEARNING

by

Chun-I Chao
Charles M. Reigeluth

IDD&E Working Paper No. 22
February, 1986

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ABSTRACT

This study investigated the effects of different structures of a synthesizer and formats of the generality component on application and remember levels of learning. Seventy-three college students from Syracuse, New York participated.

Four treatment groups were formed by combining two types of structure (complete vs. partial) with two types of format in generality (visual vs. verbal statement). A complete synthesizer contained a generality, an example and some practice. A box-chart diagram was used to represent the visual format of the generality.

Results suggest that "format" of generality does not make significant differences on either application or remember level of learning. But a complete synthesizer seems to benefit remember level learning. When comparing treatment groups with control group, the post-hoc comparison again shows that complete synthesizers result in significantly better learning than no synthesizer at all. Some possible reasons for findings are discussed at the end.

INTRODUCTION

A Context for Synthesizer

Instructional design is concerned with understanding, improving and applying methods of instruction in order to make learning more effective, more efficient and more appealing (Reigeluth, 1983). However, despite the fact that educational activities have existed for a long time, the field of instructional design did not appear as a science until the middle of the 20th century.

Instructional design found its own stance since the late 1950s, but has maintained a close relationship with behavioral psychology and cognitive psychology. Many instructional theories employing either approach have emerged. Among the theorists are Skinner, Bruner, Ausubel, Gagne, Gilbert, Glaser, and more recently, Landa, Scandura, Merrill, Gropper, Reigeluth, Markle, and others. These theories are prescriptive in the sense that they provide bases for deciding which instructional methods should be used in a given situation to achieve the desired outcomes.

Since instructional design is a prescriptive science, it is concerned with prescribing optimal "methods" as opposed to describing actual "outcomes." Three types of methods were identified by Reigeluth (1983): organizational strategies, which deal with organizing the subject-matter content; delivery strategies, which deal with conveying the content; and management strategies, which deal with making decisions about how and when to use the previous two strategies. A further classification was made on the organizational strategies. One is micro strategies, which are concerned with teaching a single idea (i.e. a concept, a principle or a procedure); the other is macro strategies, which are concerned with teaching more than one idea, and this is where strategies such as sequencing, synthesizing and summarizing come into play.

With respect to macro strategies, many research efforts have been made to identify sequencing principles (Resnick, 1976; Tyler, 1950; Thomas, 1963; Posner & Strike, 1976). Some instructional theories have prescriptions on how to sequence the content, such as Gagne's hierarchical approach, Landa's snowball approach, Ausubel's progressive differentiation approach, and Reigeluth's elaboration approach. "Summarizing" (or systematic review) has also been a long-used strategy, although not many theories or models have provided specific guidance on effective use of it. Synthesizing however is the least discussed, if not the least used, strategy in instruction. For better learning, most learning tasks require a synthesizing effort on the part of the learners. Looking from the information processing point of view, synthesizing is extremely important in that it makes learning more meaningful by relating new information to the learner's existing knowledge, and showing the relationships among the various pieces. To synthesize is to put together all the piecemeal knowledge into a big picture and to make an integrated under-

standing of it. Thus, a good synthesizing strategy on the part of the instructor can help the learner identify the relationships among pieces, so that each piece of knowledge becomes more meaningful in an integrated, macroscopic context.

Theoretical Framework

As mentioned before, only a few early theorists have expressed a concern about synthesizing strategies. Bruner and Ausubel are the two major persons among them. Bruner (1960) talked about gaining meaningful learning by acquiring the "structure" of a subject. The "structure" referred to the relationships among content elements. Similarly, Ausubel (1968) discussed "integrative reconciliation" as an important concern for the instructional process. He described "integrative reconciliation" as a process of continuous interaction and recombination of newly acquired information with preexisting elements of cognitive structure to form new meaning and new organization of knowledge.

One of the recent instructional theories that shows a great concern about synthesizing and provides a set of guidelines for operationalization is the Elaboration Theory (Reigeluth, 1979; Reigeluth & Stein, 1983). This theory is concerned with four kinds of macro strategies: selection, sequencing, synthesizing and summarizing of subject matter content. The strategy component that Elaboration Theory uses for synthesizing is called the "synthesizer." According to the Elaboration Theory, the purpose of a synthesizer is to relate and integrate the individual ideas of a single type of content (i.e. concept, principle or procedure). It is hypothesized to have the effects of 1) providing students with valuable knowledge, 2) facilitating a deeper understanding of the individual ideas, 3) increasing the meaningfulness and motivational effect of new knowledge, and 4) increasing retention. These effects were proposed based on knowledge about human cognitive functions. It is assumed that by comparing and contrasting the individual ideas within the content, a broader picture can be shown which provides additional knowledge about the content and helps with a better understanding of it. Also, the periodical integration of new knowledge and the learner's prior knowledge takes advantage of the learner's developing cognitive structure, which then makes learning more meaningful and unforgettable.

Two kinds of synthesizers were identified by Reigeluth and Stein (1983): an internal synthesizer, which shows relationships among the new ideas within a lesson; and a within-set synthesizer, which shows horizontally the relationships among the ideas at a given level of elaboration, and vertically the relationships between these ideas and the more general, inclusive ones that subsume them.

Elaboration Theory proposes that a synthesizer should consist of 1) a generality in the form of a subject-matter structure for the organizing content, 2) a few prototypical examples, and 3) a few integrated, diagnostic, self-test practice items. Both the

internal and within-set synthesizers should be placed at the end of each lesson. The generality in a synthesizer is one or more subject matter structures plus the necessary verbal description to clarify their meanings (Reigeluth, Merrill & Bunderson, 1978; Reigeluth & Stein, 1983). The examples in a synthesizer portray the interrelationships among instances of the ideas that are being synthesized. The practice in a synthesizer is a set of items on the interrelationships among the ideas (Reigelugh & Darwazeh, 1982).

Previous Research

It was mentioned earlier that the emergence of the idea of synthesizing can be traced back to 1960, but this idea of teaching the content structure was not opertionalized well in early research and theories.

One of the early strategies for teaching the structure of a subject was the "advance organizer" proposed by Ausubel (1960). According to Ausubel, the advance organizer is a brief description of the content at a high level of abstraction, which is given at the beginning of the lesson. It is supposedly to provide relevant subsuming concepts, in order to facilitate the assimilation of new information as well as the process of integrative reconciliation. However, Ausubel's advance organizer is so general, inclusive, and abstract, that it says nothing about the actual content to be learned. A review by Van Patten, Chao and Reigeluth (in press) revealed that, since the advance organizer does not explicitly teach the structure of the content, it is not a synthesizer in the Elaboration Theory's definition of the term, even though it is likely to result in the building of stable cognitive structures and therefore in the learning of some relationships. Van Patten et al. further reasoned that if any knowledge about the content structure was ever obtained, it might be either due to some abilities of the learner or "the learner's borrowing of a relevant set of content interrelationships from previously learned materials." Above all, the major criticism about the advance organizer is that Ausubel did not provide a definite way of constructing it.

Merrill and Stolurow (1966) tried to construct an organizer based on content interrelationships. They arranged the content elements in a hierarchical order such that "each succeeding statement was a combination, reorganization, elaboration or application of previous principles." (p.253) However, although the hierarchical organizer was developed based on the content structure, this structure (the relationships among ideas) was not presented explicitly to the learners.

Strictly speaking, there has been very little research on synthesizing which operationalizes the idea in a precise, replicable and explicit way. To the knowledge of the authors, Elaboration Theory is the first one which addresses this problem and prescribes the structure, development and uses of synthesizing strategies. Nevertheless, empirical testing is needed to vali-

date its prescriptions about synthesizers and to find out which formats are most effective in communicating the interrelationships among content elements, an aspect not yet clearly defined by the Elaboration Theory.

Some relevant research studies have been done recently. Two studies (Frey & Reigeluth, 1981; Carson & Reigeluth, 1983) investigated the effects of different positions of a conceptual synthesizer in relation to sequencing strategies. Although both of them used tree-chart diagrams as the format for conceptual synthesizers, "format" was not deliberately examined in terms of the effects of its variations.

The first study on "format" was conducted by McLean, Yeh and Reigeluth (1983). They investigated the effectiveness of three formats of conceptual synthesizers: 1) tree-chart diagram (visual-only), 2) prose form (verbal-only), and 3) tree-chart and prose in combination (visual-verbal combination). The results suggest that when teaching conceptual relationships, visual-only format is superior to either verbal format or visual-verbal combination.

One noteworthy thing is that all the above studies on synthesizers used the Elaboration Theory as their research paradigm, but none of them followed the prescriptions in terms of the structure of a synthesizer. Instead of having generalities, integrated examples and diagnostic practice in the synthesizer, they only included the generalities. Thus, the results of those studies relate to the "position" of a synthesizer in a lesson or the "format" of the generality component of a synthesizer rather than to the structure of a synthesizer.

A review of those studies also shows that the synthesizers used were all internal synthesizers, since the information contained in each synthesizer was only the coverage of one single lesson. No within-set synthesizer has ever been investigated so far. According to the Elaboration Theory, a within-set synthesizer teaches the relationships among ideas across several lessons.

Present Study

To correct for the deficiencies described above, and since there have been no studies on procedural synthesizers, this study investigates the effects of different structures of synthesizers and formats of the generality component of synthesizers using a within-set operationalization. The independent variables in this study are structure of synthesizer (complete vs. partial) and format of generality (visual vs. verbal). The dependent variables are recall of the procedures and application of them on new instances (statistical problems). The hypotheses are:

1. In both application level and remember level learning of a procedure, students who have received a box-chart (visual) generality in the synthesizer will perform better than those who have received a verbal generality.

2. In application level learning of a procedure, students who have received a complete synthesizer (including generality, examples and practice) will perform better than those who have received a partial one (including generality only); but in remember level learning, they will perform equally well.

3. In both application level and remember level learning of a procedure, students who have received a synthesizer, regardless of structure of the synthesizer or format of the generality, will perform better than those in the control group who have received no synthesizer.

METHOD

Subjects

An elementary statistics class was selected from a college in Syracuse, New York. A total of seventy-three students participated in the study. Sixty percent of them were freshmen; the rest were sophomores or juniors. Ninety percent of them were white. According to the instructor, their intelligence level was a little below average.

The students were randomly assigned to five groups (described below). This was realized by randomizing the order of the booklets in advance. To minimize the size differences, this process was done in groups of five, such that every set of five booklets contained one of each group in a random order. These booklets were then distributed to the students as they showed up at the entrance to the classroom.

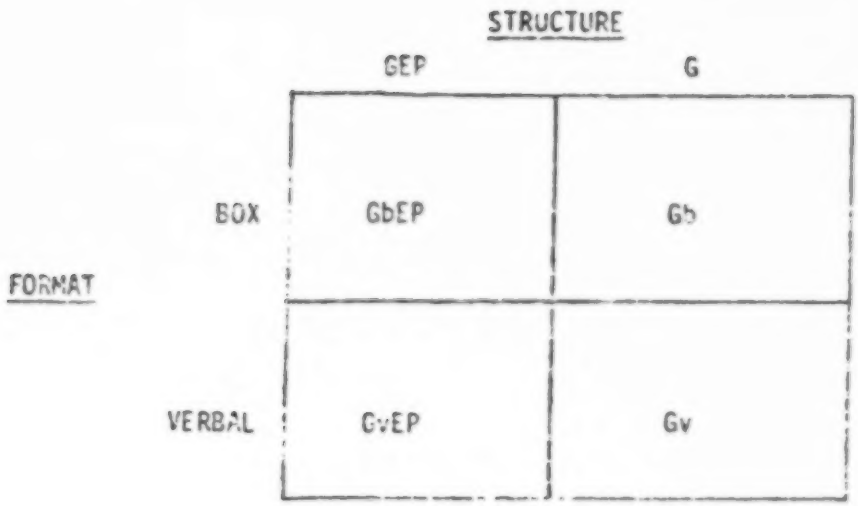
Design

A posttest-only control group design served as the experimental design. The statistical design was a 2 x 2 factorial design. The two factors were format of generality in the synthesizer and structure of synthesizer (See Figure 1). A two-way analysis of covariance was performed to test the first two hypotheses, using the students' previous class quiz scores as a covariate. A one-way analysis of covariance was performed to compare the experimental groups with the control group for the third hypothesis. When significance was found, a post-hoc comparison, using the Dunnet procedure was performed to determine which experimental groups were significantly different from the control group.

Insert Figure 1 about here

Instructional Task and Materials

In order to develop a true within-set synthesizer, the procedural synthesizer used in this study covered the content of 13



Legend:

G = Generality
E = Example
P = Practice
b = box-chart generality
v = verbal generality

Figure 1. 2 × 2 Factorial Design

weeks' instruction at the college level. Each week's instruction (for a three-credit-hour course) can be translated into six hours of learning (three hours of in-class learning and three hours of homework). So there was a total of seventy-eight hours of learning. The Elaboration Theory tentatively proposes that 7±4 10-hour lessons would be an optimal amount of coverage for a within-set synthesizer. Thus, the amount of instruction covered for this study was deemed legitimate.

The materials were presented in the form of a self-instructional booklet. For the convenience of administration, the color of booklets for each treatment group was different. The materials for those in the four experimental groups were a synthesizer which illustrated the relationships between the statistical tests they had learned so far in the course and the problem conditions under which they are appropriate. This particular content was chosen because these tests were taught individually throughout the semester, and no synthesizing effort was ever made to show the students, in a comparative or contrasting way, the differences among these tests and the relationships between them and their corresponding problem conditions.

The material for the control group was a summary of formulas for all the statistical tests taught in the course. No synthesizing information was given.

The tasks in the practice and post test were to recall the relationships illustrated in the synthesizer, and to apply them to given problems, in order to decide which tests should be used. The author worked with the instructor throughout the material/test development process, so the content was approved by the instructor in terms of accuracy and level of difficulty.

Each booklet was prefaced by a few instructions explaining the purpose of the following study and the time allowed. They were identical for all the groups.

Treatments

The four experimental groups received different versions of the synthesizer. These versions differed in two ways: a) using a box-chart or a series of verbal statements as the generality; b) containing the generality, example and practice or the generality only. Thus, the four experimental treatments were: 1) box-chart generality with example and practice (GbEP); 2) verbal generality with example and practice (GvEP); 3) box-chart generality only (Gb); 4) Verbal generality only (Gv) (See Figure 1). The box-chart generality and verbal generality are presented in Figures 2 and 3, respectively.

For those groups which received the example and practice in addition to the generality, one example was given, along with explanations as to how the appropriate test was chosen (See Figure 4), and two practice items were given with the answers (no explanations) provided on the next page (See Figure 5). The example and practice were identical for these groups.

The control group received a totally different but still course-related treatment which was a summary of the computational formulas for all the statistical tests taught in the course (See Figure 6).

Insert Figures 2, 3, 4, 5 and 6 about here

Tests and Measures

The posttest consisted of 36 short-answer questions which measured both remember level learning and application level learning. To test remember-learning, the students were asked to recall the test selection criteria described in the generality of the synthesizer (the relationships between problem conditions and tests). To test application-learning, they were asked to use the selection criteria to come up with the most appropriate test procedure for a given problem. No calculation was required. There were 16 test items on the remember level and 20 on the application level. The test items were randomly sequenced. Some test items are shown in Figure 7.

Insert Figure 7 about here

Administration

The study was carried out in the second-to-last class, which was scheduled to be a review session. The class lasted for 60 minutes. When a student came to the class, s/he was given two booklets -- one study guide (synthesizer) and one test booklet, and was instructed to sit in the assigned section of the classroom. Since some groups required more reading time than others due to the natures of the different treatments, the following rules were set for seat assignment: the Gb, Gv, and control groups, which had 10 minutes to study the synthesizer, were told to sit in the first five rows; the GbEP and GvEP groups, which had 20 minutes to study the synthesizer, were told to sit in the next three rows. The students were told not to proceed with the test booklet until they were told so.

When the time for study guide was up, the study guides were collected, and the students could begin the test. There was no time restriction on the test. Most of them finished it in 30 minutes.

The instructor administered the whole process, while the author appeared as a class assistant. The students were told by the instructor that the purpose of this session was to see how helpful the different review strategies he had developed were in helping student learning. They were also told that the test offered a make-up chance for those who did not perform well in the previous ones. Poor performance would not affect their final

Statistical Hypothesis Testing

Parametric tests	Tests on mean(s)	Value of one mean ($H_0: \mu = \mu_0$) or difference between two means ($H_0: \mu_1 = \mu_2$)	Population standard deviation (σ) is known		NORMAL TEST (Z)
			Population standard deviation (σ) is unknown, sample standard deviation (s) is used	Large sample ($N \geq 30$)	NORMAL APPROXIMATION (Z)
				Small sample ($N < 30$)	t TEST
		Differences between more than two means ($H_0: \mu_1 = \mu_2 = \mu_3 \ldots$)			F TEST
	Tests on proportion(s)	One proportion ($H_0: p = p_0$) or difference between two proportions ($H_0: p_1 = p_2$)			NORMAL APPROXIMATION (Z)
		Differences between more than two proportions ($H_0: p_1 = p_2 = p_3 \ldots$)			CHI SQUARE TEST (X^2)
	Tests on relationships (independence) between two variables with a contingency table				CHI SQUARE TEST (X^2)
Non-parametric tests	Tests on median(s)	Value of one median ($H_0: \xi = \xi_0$)			SIGN TEST
		Difference between two medians ($H_0: \xi_1 = \xi_2$)		Larger $n > 10$	NORMAL APPROXIMATION (Z) with RANK-SUM
				Larger $n \leq 10$	RANK-SUM TEST
	Tests on relationships (independence) between two variables				RANK CORRELATION COFFICIENT

* To read the chart, start from the left-most column, and look for the box that matches the situation given in your problem. Once it has been identified, move to the boxes on the right had side of it, and again choose the one which matches your problem. Keep repeating the same process until you reach the last column, which will give you the name of the appropriate test for your problem.

Figure 2. The Box-chart Generality for the Synthesizer

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Statistical Hypothesis Testing

There are primarily two types of hypothesis testing -- parametric and non-parametric.

Parametric Testing

There are three kinds of problems taught in this course that can be solved by parametric methods -- tests on mean(s), tests on proportion(s), and tests on relationships (independence) between two variables.

For problems which requrie a test on the value of one mean($H_0: \mu = \mu_0$), or the difference between two means ($H_0: \mu_1 = \mu_2$), use the NORMAL TEST (Z) if the population standard deviation (σ) is known; use the NORMAL APPROXIMATION (Z) if σ is unknown, sample standard deviation (s) is used, and the sample size is large ($N \geq 30$); use the t TEST if σ is unknown, s is used, and the sample size is small ($N < 30$).

For problems which requrie a test on the differences between more than two means ($H_0: \mu_1 = \mu_2 = \mu_3 \ldots$), use the F TEST.

For problems which require a test on the value of one proportion ($H_0: P = P_0$), or the difference between two proportions ($H_0: P_1 = P_2$), use the NORMAL APPROXIMATION (Z).

For problems which require a test on the difference between more than two proportions ($H_0: P_1 = P_2 = P_3 \ldots$), use the CHI SQUARE TEST (X^2).

For problems which require a test on the relationships (independence) between two variables with a contingency table, use the CHI SQUARE TEST (X^2).

Non-parametric Testing

There are two kinds of problems taught in this course that can be solved by non-parametric methods -- tests on median(s) and test on the relationships (independence) between two variables.

For problems which require a test on the value of one median ($H_0: \xi = \xi_0$), use the SIGN TEST.

For problems which requre a test on the difference between two medians ($H_0: \xi_1 = \xi_2$), use the NORMAL APPROXIMATION (Z) with RANK-SUM if the larger $n > 10$; use the RANK-SUM TEST if the larger $n \leq 10$.

For problems which require a test on the relationships (independence) between two variables, use the RANK CORRELATION COEFFICIENT.

Figure 3. The Verbal Generality for the Synthesizer

Example

The following is an example which illustrates how the information provided in the previous page is used in arriving at the appropriate statistical test.

Problem

An investigation of two kinds of photocopying equipment showed that 60 failures of the first kind of equipment took on the average 84.2 minutes to repair with a standard deviation of 19.4 minutes, while 60 failures of the second kind of equipment took on the average 91.6 minutes to repair with a standard deviation of 18.9 minutes. Test whether there is a real difference between the two means at $\alpha = 0.01$.

Solution

The last sentence in the question tells us that the problem requires a test on means, and further that it requires a test on the difference between two means. Remembering from the previous page, we know that the next thing is to find out if the two population standard deviations are provided. Obviously they are not (we are only given the two sample standard deviations - 19.4 minutes and 18.8 minutes). Again recalling from the previous page, we know that the final factor to be considered is the sample size. Since each sample has a size of 60, the N is larger than 30. All the above leads us to the decision that the NORMAL APPROXIMATION (Z) is the appropriate test for this particular problem.

Figure 4. An Example for the Synthesizer

Practice

The following are some problems for youto practice. You will do better on the test if you try to come up with the **NAMES** of the appropriate test on your own before looking at the answers which are given on the next page.

1. Six guinea pigs injected with 0.5 mg of a medication took on the average 15.4 seconds to fall asleep with a standard deviation of 2.2 seconds, while six other guinea pigs injected with 1.5 mg of the medication took on the average 11.2 seconds to fall asleep with a standard deviation of 2.6 seconds. Use $\alpha = 0.05$ to test whether or not the increase in dosage from 0.5 to 1.5 mg really makes a difference in the amount of time it takes a guinea pig to fall asleep.

   Test:_____

2. On 15 occasions, a random sample, a city employee had to wait 4, 8, 7, 7, 2, 6, 8, 5, 9, 6, 1, 5, 6, 5, and 9 minutes for the bus he takes to work. Test the null hypothesis that the median is equal to 5 against the alternative hypothesis that it is not at $\alpha = 0.05$.

   Test:_____

Answers for Practice

1. t Test

2. Sign Test

Figure 5. Practice items for the synthesizer

The following information summarizes the formulas of all the statistical tests you have learned this semester. You have 10 minutes to study. It will then be collected and you will be given the test.

σ^2 – population variance

σ – population standard deviation

s^2 – sample variance

s – sample standard deviation.

$\sigma_{\bar{x}}$, $s_{\bar{x}}$ – standard deviation of the sample mean

Z test

$$z = \frac{\bar{X} - \mu}{\sigma_{\bar{x}}} = \frac{\bar{X} - \mu}{\frac{\sigma}{\sqrt{n}}}$$

$$z = \frac{\bar{X}_1 - \bar{X}_2}{\sigma_{\bar{x}_1 - \bar{x}_2}} = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\sigma_{\bar{x}_1}^2 + \sigma_{\bar{x}_2}^2}} = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}}$$

Normal Approximation

$$z = \frac{\bar{X} - \mu}{s_{\bar{x}}} = \frac{\bar{X} - \mu}{\frac{s}{\sqrt{n}}}$$

$$z = \frac{\bar{X}_1 - \bar{X}_2}{s_{\bar{x}_1 - \bar{x}_2}} = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{s_{\bar{x}_1}^2 + s_{\bar{x}_2}^2}} = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

$$z = \frac{\hat{p} - p}{\sigma_{\hat{p}}} = \frac{\hat{p} - p}{\sqrt{\frac{pq}{n}}} \qquad (q = 1 - p)$$

$$z = \frac{\hat{p}_1 - \hat{p}_2}{\sigma_{\hat{p}_1 - \hat{p}_2}} = \frac{\hat{p}_1 - \hat{p}_2}{\sqrt{\frac{p_1 q_1}{n_1} + \frac{p_2 q_2}{n_2}}} \qquad (q_1 = 1 - p_1;\ q_2 = 1 - p_2)$$

FIGURE 6. TREATMENT FOR THE CONTROL GROUP

For the following questions, give the NAME of the appropriate test or the PROBLEM CONDITION(S) for a particular test in the space provided below each question. NO CALCULATION is required.

Test on remember-learning

1. What is (are) the condition(s) under which the rank correlation coefficient should be used?

   Condition(s): _____

2. Once you have determined that a given problem is about proportions, which decision should you make next?

   _____

3. Given a problem which requires a test on the value of one mean, if $N \geq 30$, and sample standard deviation (s) is used, which test would be appropriate?

   Test: _____

Test on application-learning

1. A random sample of 12 graduates of secretarial school averated 73.8 words per minute with a standard deviation of 7.9 words per minute on a typing test. How should we decide to accept or reject an employer's claim that the school's graduates averate less than 75.0 words per minute?

   Test: _____

2. One method of seeding clouds was successful in 57 of 150 attempts, while another method was successful in 33 of 100 attempts. Set α =0.05 and test the null hypothesis that both methods are equally good.

   Test: _____

3. In a random sample of 10 issues, a newspaper listed 32, 27, 41, 52, 31, 22 38, 45, 34, and 36 apartments for rent. Set α =0.05 and test the hypothesis H_o: $\mathcal{E}$ (median) = 40.

Figure 7. Test Items

grades, but outstanding performance could result in 10 points more in the final grading.

RESULTS

Hypothesis 1: It was predicted that in both application and remember levels of learning, students who have received a box-chart (visual) generality in a synthesizer will perform better than those who have received a verbal generality. Results from the two-way analysis of covariance did not support this hypothesis. No main effect was found in the "format" of generality in both levels of learning (See Tables 1 and 2).

Hypothesis 2: It was predicted that in application level learning, students who have received the generality, examples and practice in a synthesizer will perform better than those who have received the generality only. Results again did not support this hypothesis. However, a main effect was found unexpectedly in the remember level. An F value of 5.81 was obtained, significant at the .02 level (See Tables 1 and 2).

Insert Tables 1 and 2 about here

Hypothesis 3: It was predicted that in both application and remember levels of learning, students who have received a synthesizer, regardless of structure and format of the generality, will perform better than those who have received no synthesizer. The one-way analysis of covariance yielded an F value of 4.83 for remember-learning, significant at the .002 level; and 2.31 for application-learning, marginally significant at .07 level. They are the results after removing the effect of student entry abilities (See Table 3). The adjusted means were used in the Dunnet procedure with a simultaneous error rate of .05, which compared each experimental group with the control group. Results of this post hoc comparison show that for both levels of learning, only the GbEP and GvEP groups were significantly better than the control group. The Dunnet's results are shown in Table 4.

Insert Tables 3 and 4 about here

DISCUSSION

The results, although not strongly supportive of the hypotheses, do provide some insights about synthesizers. First, with respect to the format of a synthesizer, although the means were in the predicted direction, it seems that the format of a procedural synthesizer does not make much of a difference. However,

Table 1. Results of Two-way Analysis of Covariance on Remember-level Learning

Effect	Adjusted mean (Standard Error) and N for each group				DF	F	P
Structure	GEP 10.48 (0.65), 29		G 8.24 (0.66), 29		1, 53	5.81	.02*
Format	Box 9.45 (0.70), 26		Verbal 9.27 (0.63), 32		1, 53	0.03	.85
Structure * Format	GbEP 10.47 (0.95), 14	GvEP 10.48 (0.92), 15	Gb 8.42 (1.02), 12	Gv 8.05 (0.85), 17	1, 53	0.04	.83

Table 2. Results of Two-way Analysis of Covariance on Application-level Learning

Effect	Adjusted mean (Standard Error) and N for each group				DF	F	P
Structure	GEP 12.04 (0.75), 29		G 10.71 (0.77), 29		1, 53	1.53	.22
Format	Box 11.16 (0.82), 26		Verbal 11.60 (0.73), 32		1, 53	0.15	.70
Structure * Format	GbEP 11.63 (1.10), 14	GvEP 12.46 (1.06), 15	Gb 10.69 (1.19), 12	Gv 10.73 (0.99), 17	1, 53	0.13	.72

Table 3. Results of One-way Analysis of Covariance

A. Remember-level learning

Effect	Adjusted Mean (Standeard Error) and N for each group					DF	F	P
	GbEP	GvEP	Gb	Gv	Control			
Group	10.66 (0.93) 14	10.47 (0.92) 15	8.64 (1.00) 12	8.10 (0.85) 17	5.77 (0.90) 15	4, 67	4.83	.002*

B. Application-level learning

Effect	Adjusted Mean (Standard Error), and N for each group					DF	F	P
	GbEP	GvEP	Gb	Gv	Control			
Group	11.85 (1.16) 14	12.40 (1.14) 15	10.95 (1.26) 12	10.76 (1.06) 17	7.92 (1.13) 15	4, 67	2.31	.07

Table 4. Dunnet's Results on Differences between Experimental Groups and Control Group

A. Remember-level differences

	GbEP	GvEP	Gb	Gv
Control	4.89*	4.70*	2.86	2.32

B. Application-level differences

	GbEP	GvFP	Gb	Gv
Control	3.93*	4.48*	3.03	2.84

Key:

* indicates differences that are significant.

G = Generality
E = Example
P = Practice
b = Box-chart generality
v = Verbal generality

McLean, et al. (1983) had found that a visual representation was better than a verbal-only representation for a conceptual synthesizer. It might be that the content they used was new to the students (the structure of a microcomputer), while the content in the present study was a familiar one, since before receiving the within-set synthesizer, the students had already studied the subject for a quite long period of time. This familiarity with the content could have helped overcome the difficulties one might have had when studying those piecemeal verbal statements. Thus, although a good visual synthesizer appears to be beneficial for learning the content structure of a new subject (McLean et al., 1983), when it comes to a familiar one, it may not be appreciably superior.

Secondly, with respect to the structure of a synthesizer, having only a generality in the synthesizer appears to be insufficient. This study supports the prescriptions of Elaboration Theory that including a propotypical example and some practice is helpful. This helpful effect, however, contrary to our hypothesis, was found to lie in remember learning as opposed to application learning. Although this finding is unexpected, it is not surprising. Previous studies on synthesizers conducted by Frey and Reigeluth (1981); Carson and Reigeluth (1983); and McLean, Yeh and Reigeluth (1983) all found significantly increased learning of relationships among content elements. The generality of a synthesizer, be it visual or verbal, represents a condensed and brief description of the content structure. For most people, this kind of synthetic learning might be new. Therefore the example and practice included served to teach the students how to read and make sense out of these seemingly piecemeal statements. The result that the GbEP and GvEP groups performed significantly better than the other groups in remembering the relationships between problem conditions and tests implies that the example and practice provided a context for meaningful learning (Reigeluth, 1983) which enhances the retention of the interrelationships described in the generality.

The reason that providing the example and practice did not increase application learning is not clear. In fact this was the first time that application learning from a synthesizer has been measured. It is possible that since the students had been learning the subject at the application level and had taken application tests several times during the semester, their ability to answer this type of question had been raised to a level that the presence of one example and two practice items would not be much help compared to the training they had received so far.

In light of the results of the present study, we suggest that even if the provision of examples and practice may not be useful in increasing immediate application learning in a within-set synthesizer, the effect on remembering the relationships may have a positive long-term impact on application in the future when no frequent application practice and tests are available as in the classroom. But this is just for the within-set synthesizers; for internal synthesizers which are provided after a single lesson,

examples and practice may still be useful in improving application learning. More research is needed to investigate this as well as the effect of a "complete" within-set synthesizer on application learning. It is also suggested that a delayed test on application be administered in future studies to determine the long-term effect.

To sum up, this study presents additional insights as to the optimal structure of a procedural synthesizer. It seems important to have a "complete" within-set synthesizer (with examples and practice), at least for remember learning of the relationships, as the Elaboration Theory prescribes.

With respect to "format", the non-significance may imply that "format" is not as important if the content is familiar. However, it may also imply that "format" is not as important for a procedural decision synthesizer as for a conceptual synthesizer which was investigated and found significant by previous research. One can even argue that maybe another format (e.g. a flowchart instead of a box chart) would make a real difference. In spite of this, it is noteworthy that the students, when asked, did feel that the box chart was clearer than the verbal statements, and that box-chart groups did perform a little bit better than the verbal-statements groups after taking into account the entry abilities.

This study represents a beginning of the investigation of within-set synthesizers. Since it was conducted with college students, used only two kinds of "formats", and focused on procedure-decision learning only, replications are necessary with different samples and content types to determine the degree of generalizability of the results.

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